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GILLINGS SCHOOL OF
GLOBAL PUBLIC HEALTH



Building Water Infrastructure to Improve Childhood Outcomes

Interventions to Decrease Childhood Lead Exposure from Private Wells

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Department of Environmental Sciences and Engineering
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University of North Carolina at Chapel Hill**

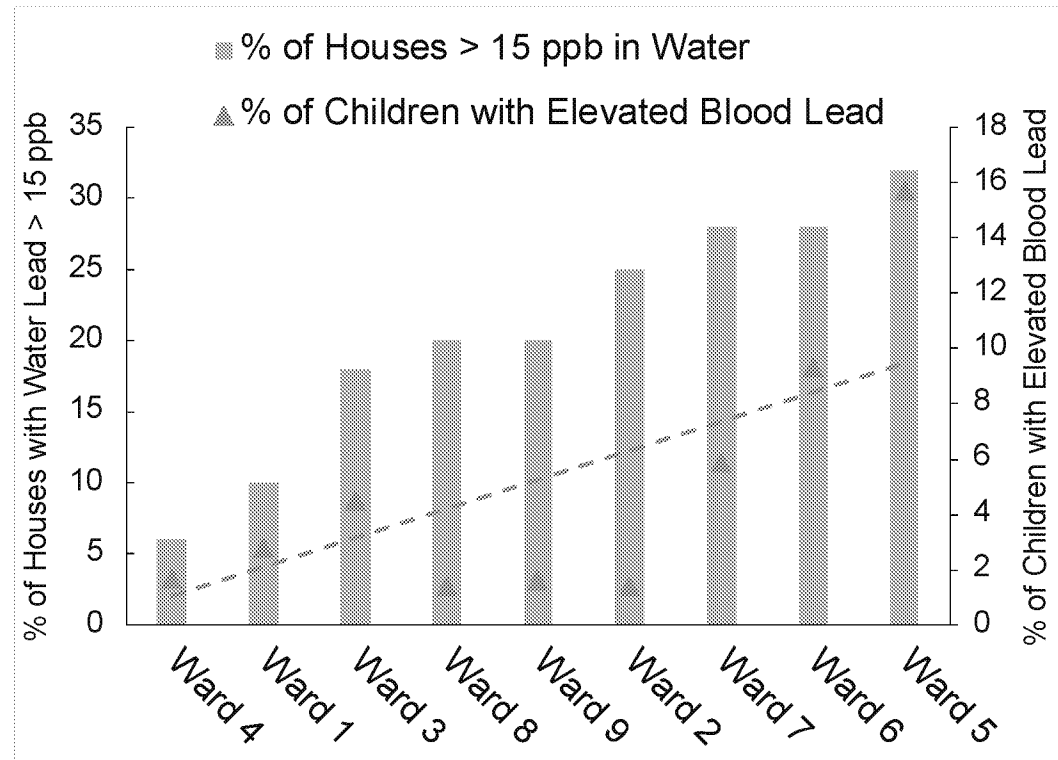
August 13, 2018

Outline

- **Motivation for research**
 - **Discovery of lead in drinking water in “underbounded” areas of North Carolina**
- **Overall research objective**
 - **Total environment framework**
- **Research team**
- **Specific tasks and methods (overview)**
- **Progress to date**

Flint Water Crisis Renewed Attention to Lead Risks in Municipal Water

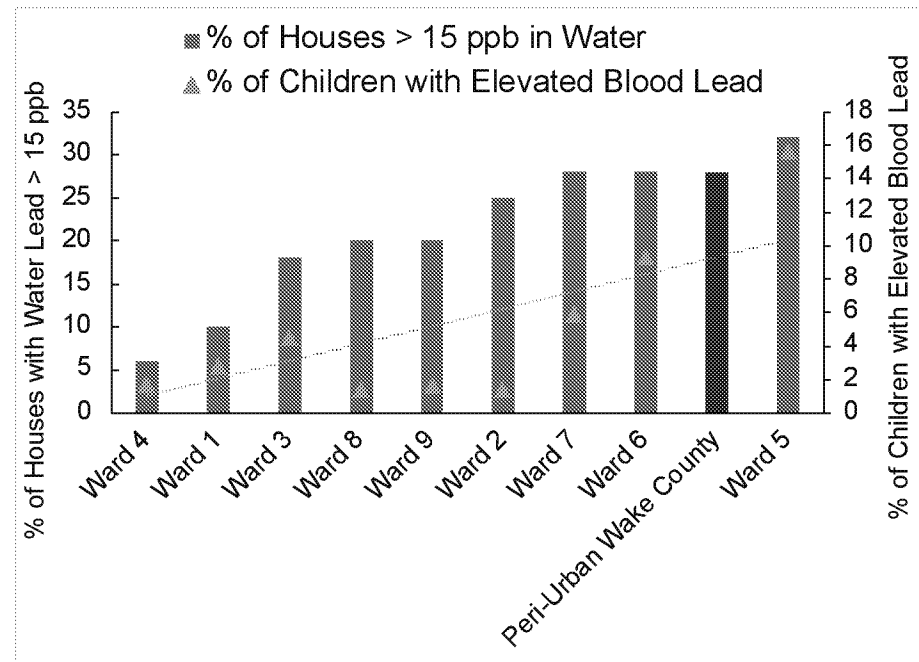
- **Blood lead increased most in most-affected wards**
- **City-wide, elevated blood lead incidence doubled (2.4 to 4.9%)**



SOURCE: Adapted from Hanna-Attisha M, LaChance J, Sadler RC, Champney Schnepf A. 2015. Elevated blood lead levels in children associated with the Flint drinking water crisis: a spatial analysis of risk and public health response. Am J Public Health 106:e1–e8.

Peri-Urban Minority Communities Could Face Risks Similar to Flint

- **My group recently found elevated water lead in 28% of households.**
 - **Majority African American peri-urban Wake County, NC**
 - **Lack municipal water service**
 - **Rely on unregulated private wells**



SOURCE: Stillo FJ, MacDonald Gibson J. 2018. Racial disparities in access to municipal water supplies in the American South: impacts on children's health. Int Public Heal J 10.

My Research Focuses on “Underbounded” Communities

- **Geographer Charles Aiken proposed the term
“municipal underbounding:**

**“Selectively expand[ing] the corporate boundary to
exclude blacks.”**

Race as a Factor in Municipal Underbounding

**Annals of the Association of American Geographers,
1987**

Sociologists Propose A Political Power Motivation

“Annexation of predominately black fringe territory may unsettle the racial balance of power within local municipalities.”



– **Daniel T. Lichter**

**“Municipal Underbounding: Annexation and Exclusion in
Small Southern Towns”**







Rural Sociology (2007)

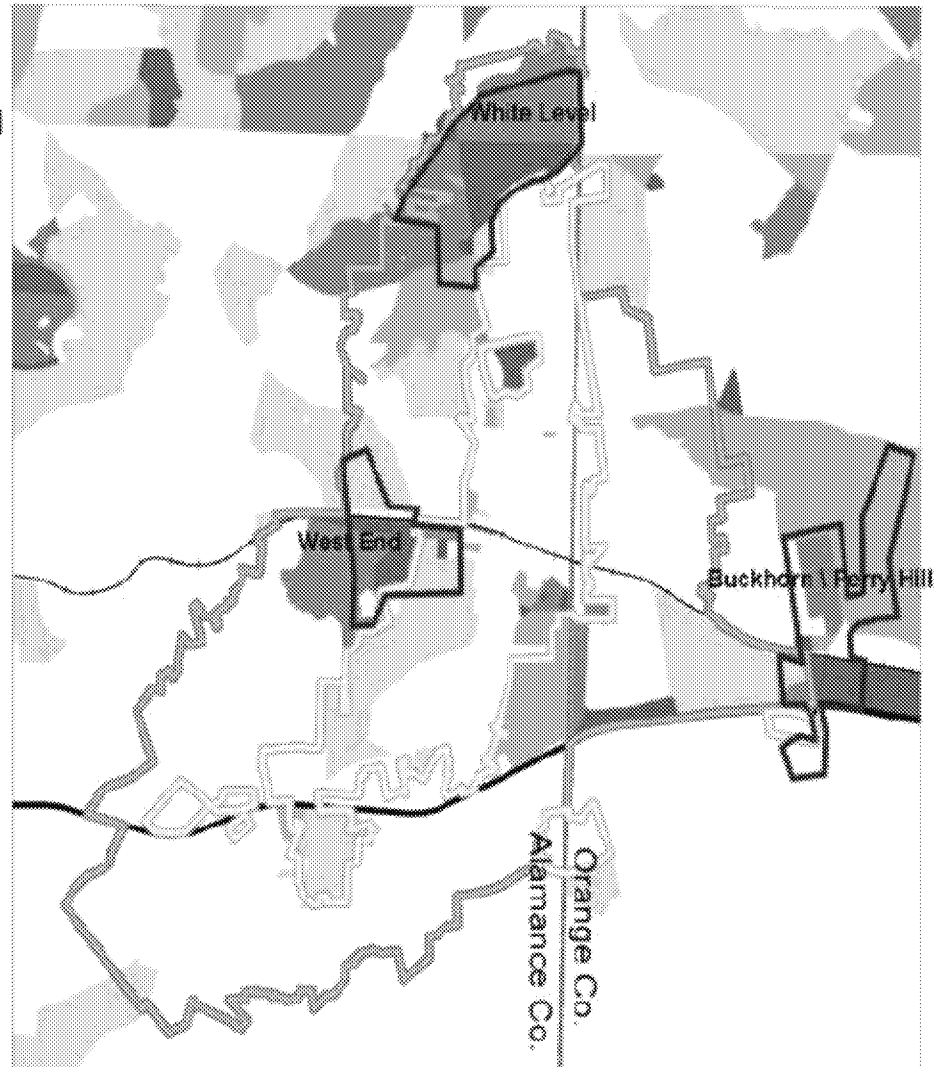
Example 1: Mebane, NC

Mebane - Racial Composition

-  Mebane City Limit
-  ETJ boundary
-  African-American Communities

Percent African-American,
Census 2000

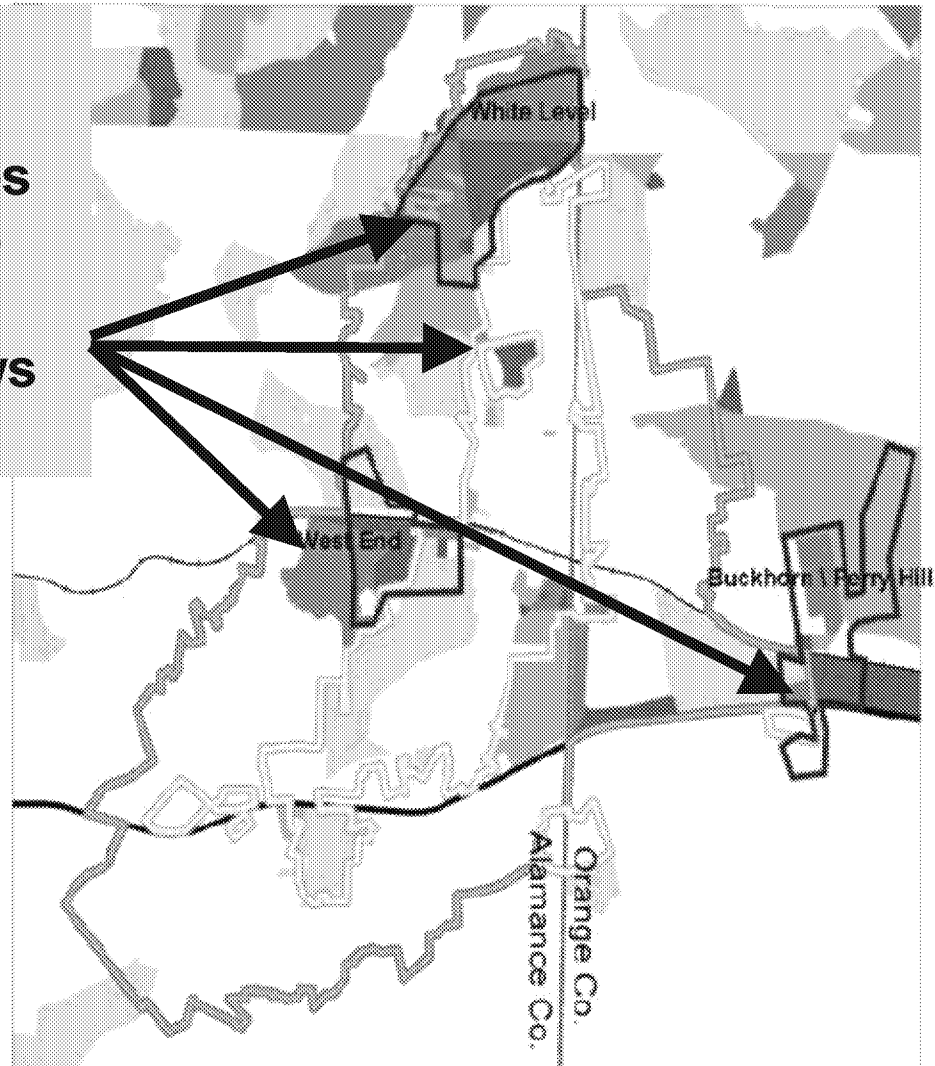
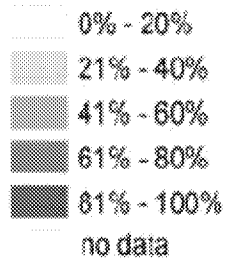
-  0% - 20%
-  21% - 40%
-  41% - 60%
-  61% - 80%
-  81% - 100%
-  no data



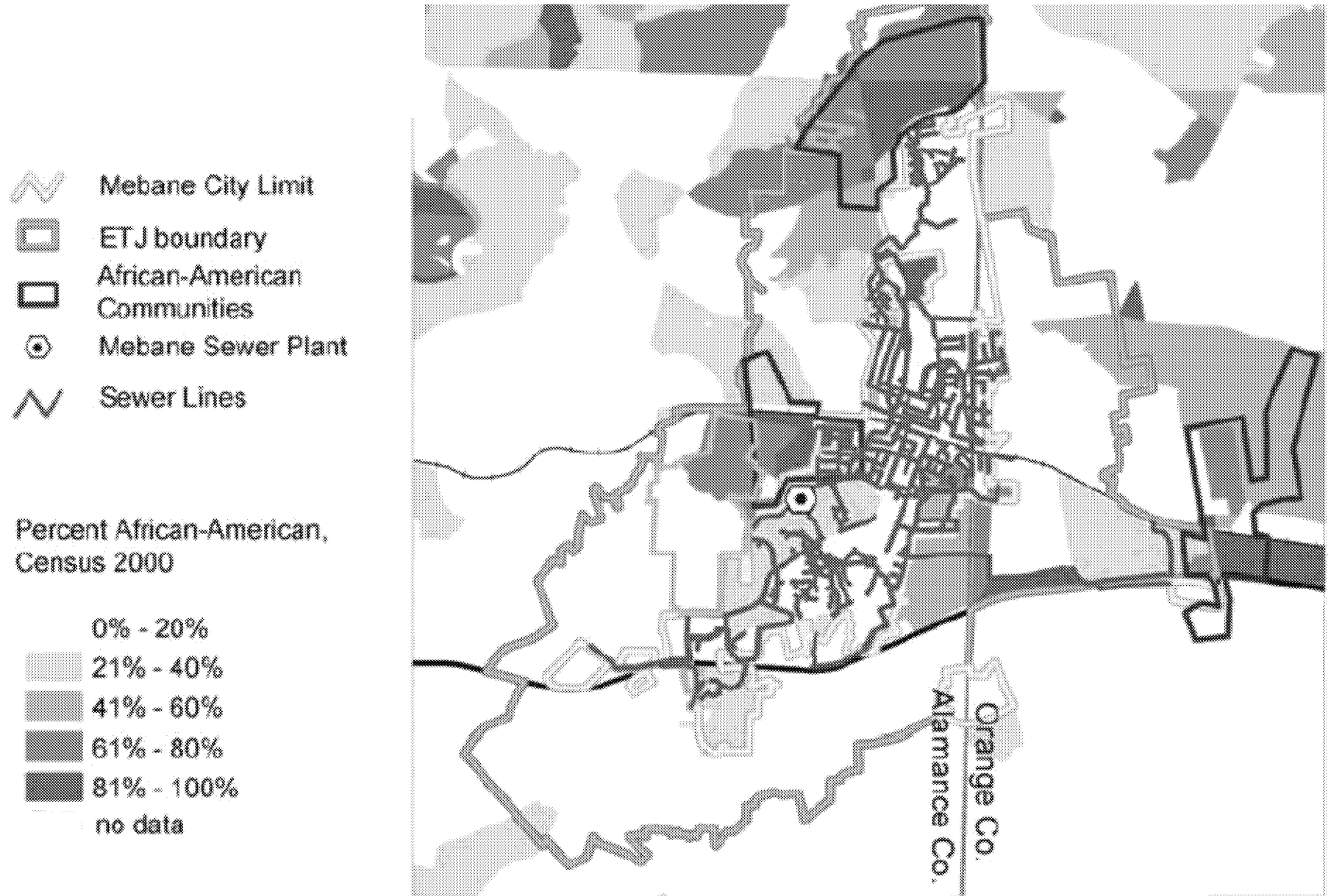
Example 1: Mebane, NC

- **Municipal boundaries exclude African American communities**
- **City controls land use via “extraterritorial jurisdiction” (ETJ) laws**

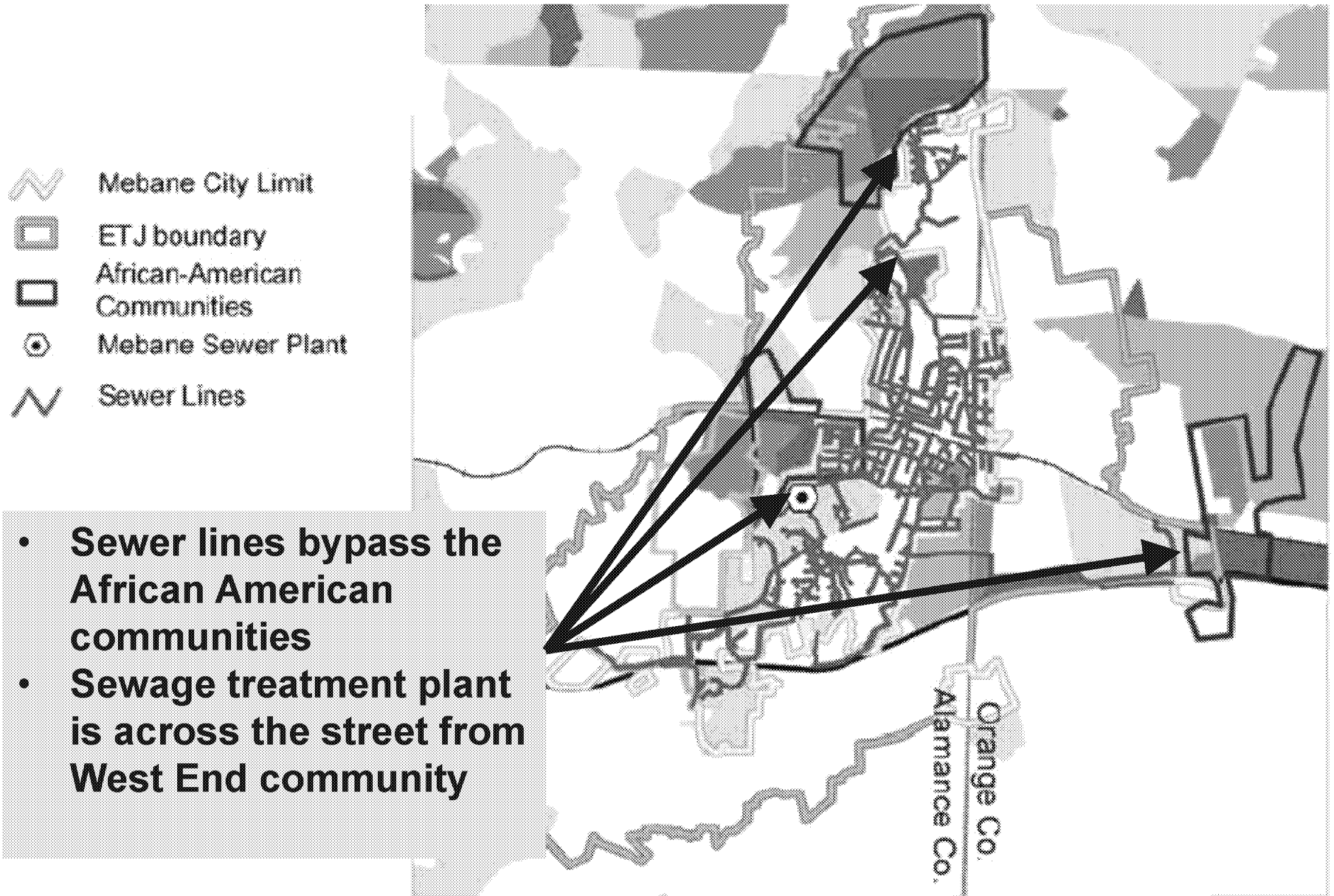
Percent African-American,
Census 2000



Sewer Lines Bypass Excluded Communities



Sewer Lines Bypass Excluded Communities



Example 2: Pinehurst, NC

In County Made Rich by Golf, Some Enclaves Are Left Behind

By SHAILA DEWAN

Published: June 7, 2005

PINEHURST, N.C., June 2- Golf has made Moore County rich. There are spas, country clubs and new \$2 million homes. The United States Open, to be held later this month on the most famous of the county's 43 golf courses, is expected to bring \$124 million to the state.

 [Enlarge This Image](#)



John Loomis for The New York Times

Maurice B. Holland Sr. empties his trash at the dump. [More Photos >](#)

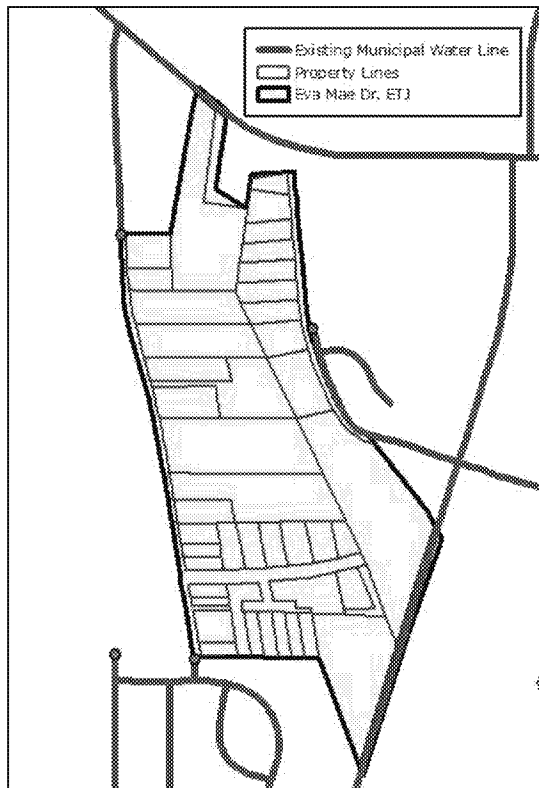
But as developers rush to provide "resort quality" amenities in the newest subdivisions, some neighborhoods have been left behind - without sewers, police service, garbage pickup or even, in some cases, piped water.

These enclaves, Jackson Hamlet, Midway and Waynor Road, are virtually all black. They butt up against, or are even completely surrounded by, affluent towns that are mostly white: Pinehurst, Aberdeen and Southern Pines.

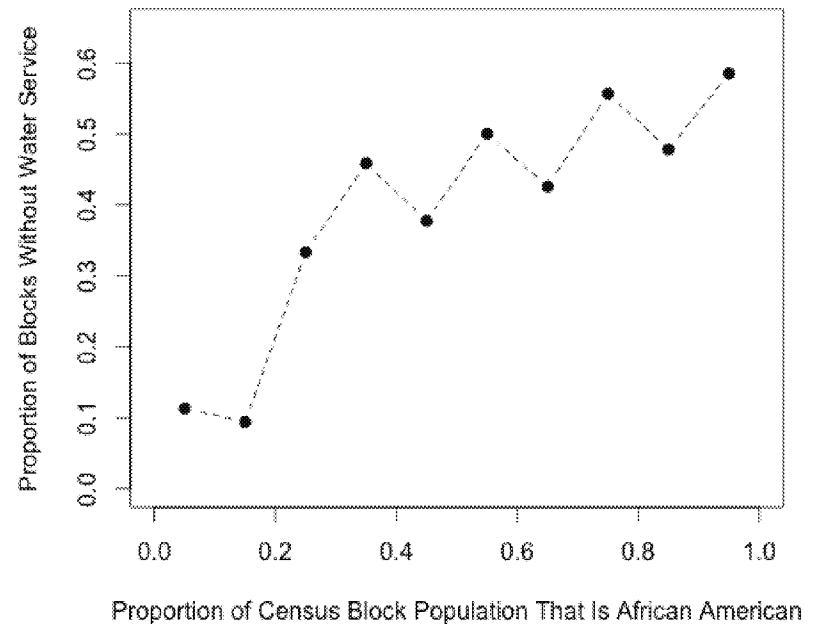
The 500 residents of these unincorporated enclaves are close enough to point out sewer lines that run past their properties en route to new developments, or to watch garbage trucks trundle past without stopping.

Example 3: Wake County, NC

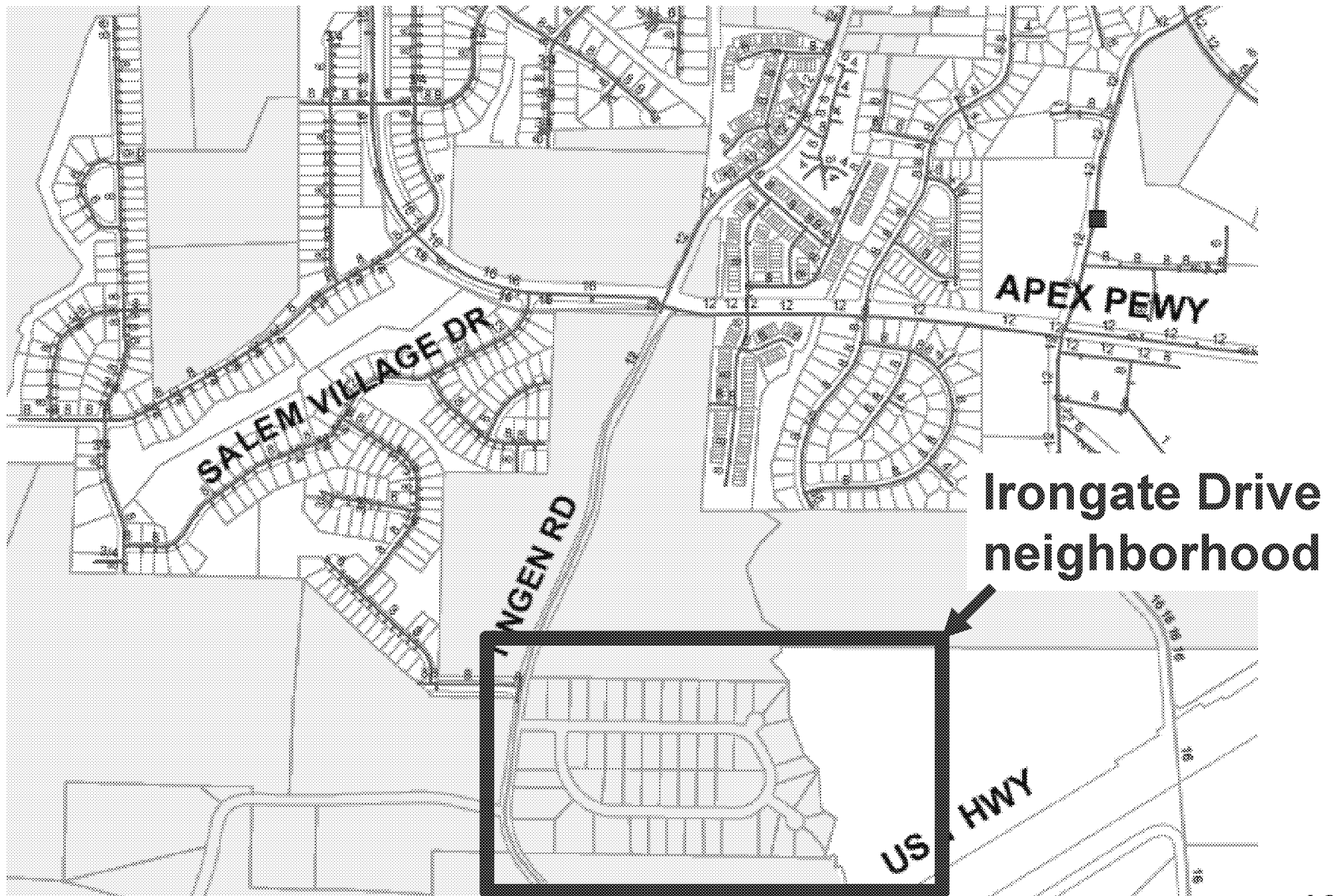
**My Group Has Mapped
“Underbounded” Areas**



**Race Is Associated with
Water Service Access**

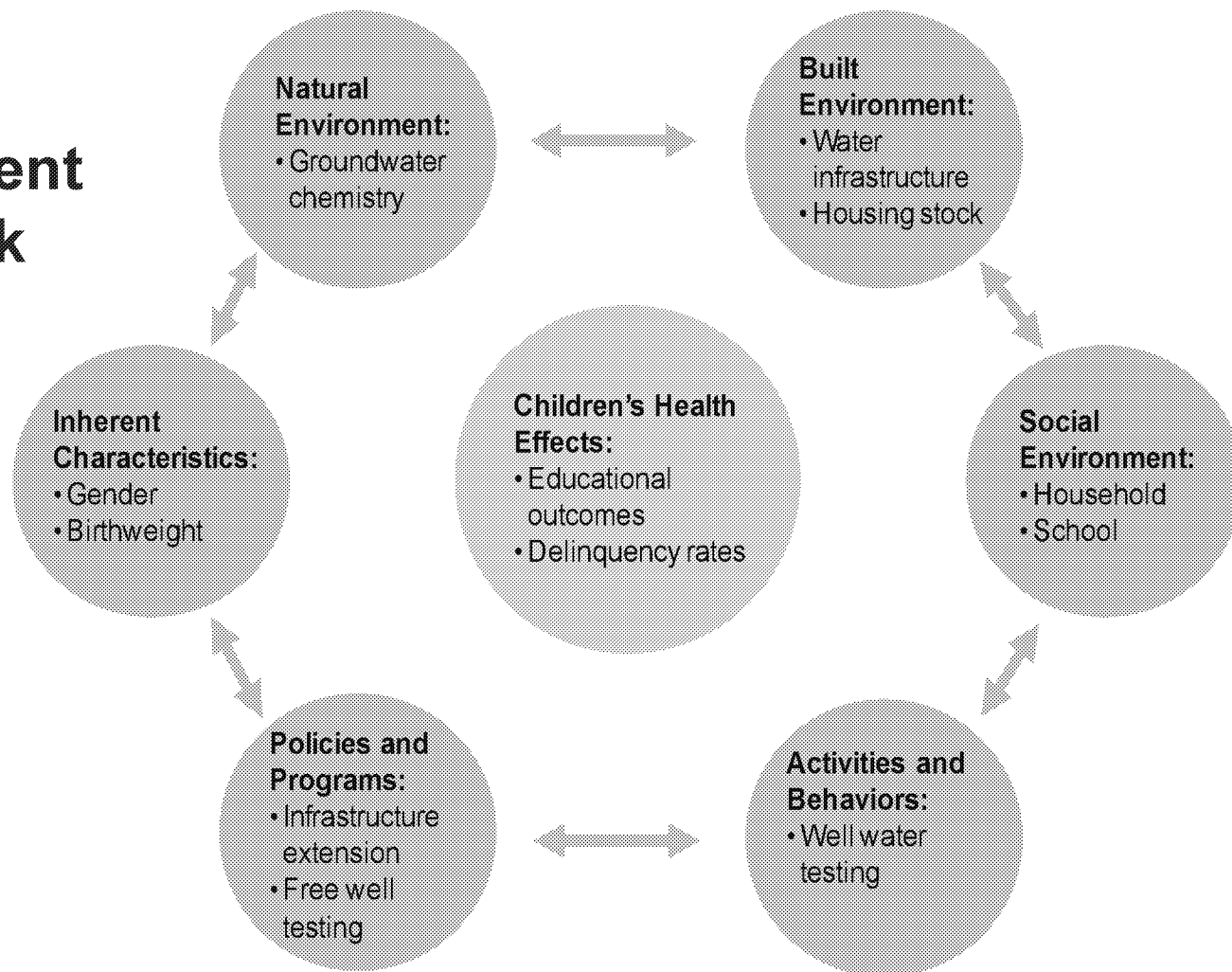


Example 4: Irongate Drive, Apex, NC



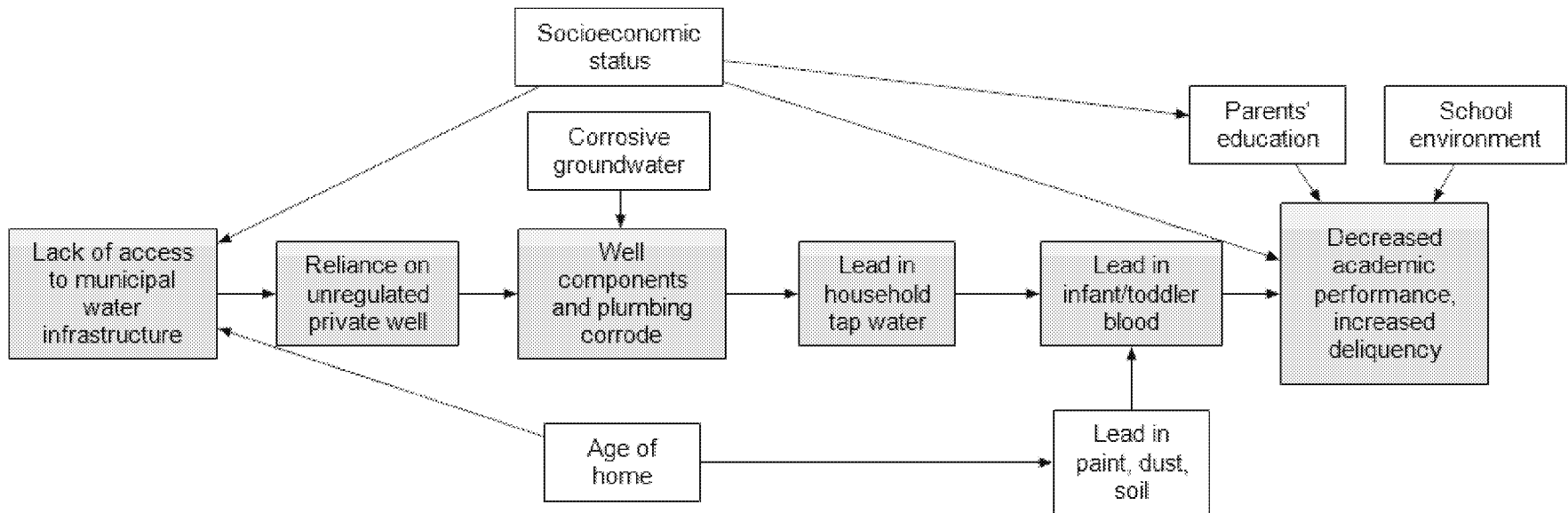
STAR Research Addresses Lead Exposure Risk in Underbounded Areas

Total environment framework



Tasks and Methods

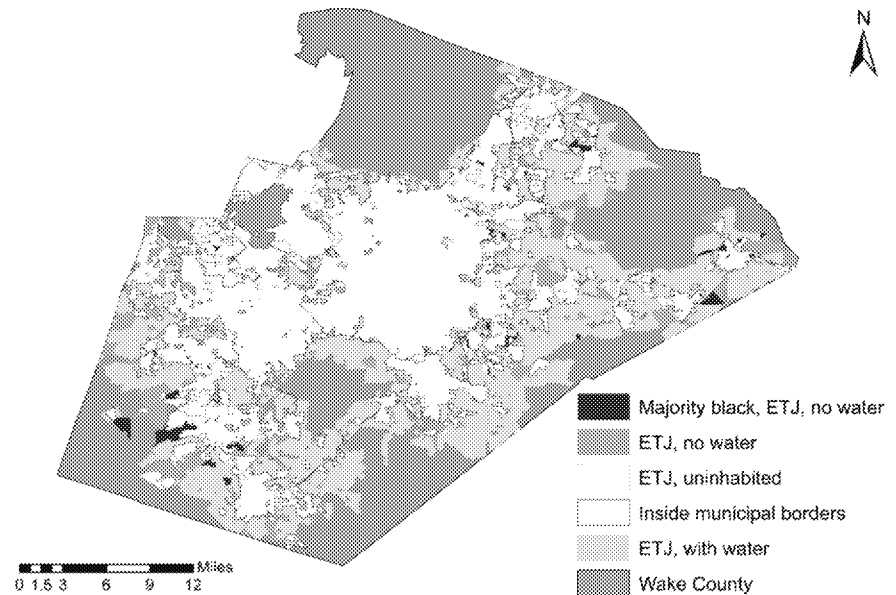
Task 1: Underbounding Effects on Children's Outcomes



Hypothesis: Exclusion from municipal water decreases educational performance and increases delinquency risk via exposure to lead in drinking water.

Task 1 Will Leverage Existing “Big” Data

- **Water source:**
 - Property tax records
- **Childhood blood lead:**
 - NC Division of Public Health, 1995—present
 - 150,000 records
- **Education outcomes:**
 - NC Education Research Data, 1995—present
 - Matched to water source
- **Juvenile delinquency:**
 - NC Division of Juvenile Justice



Will Explore Causal Chain via 2-Stage, Least-Squares Regression

- **Stage 1:**

- $BLL = \delta_0 + \vec{X}_1 \vec{\delta}_1 + \vec{X}_2 \vec{\delta}_2 + \delta_3 W + \eta$

BLL = child's blood lead level

X_1, X_2 = covariate vectors

δ_1, δ_2 = coefficient vectors

W = water source (private well or regulated system)

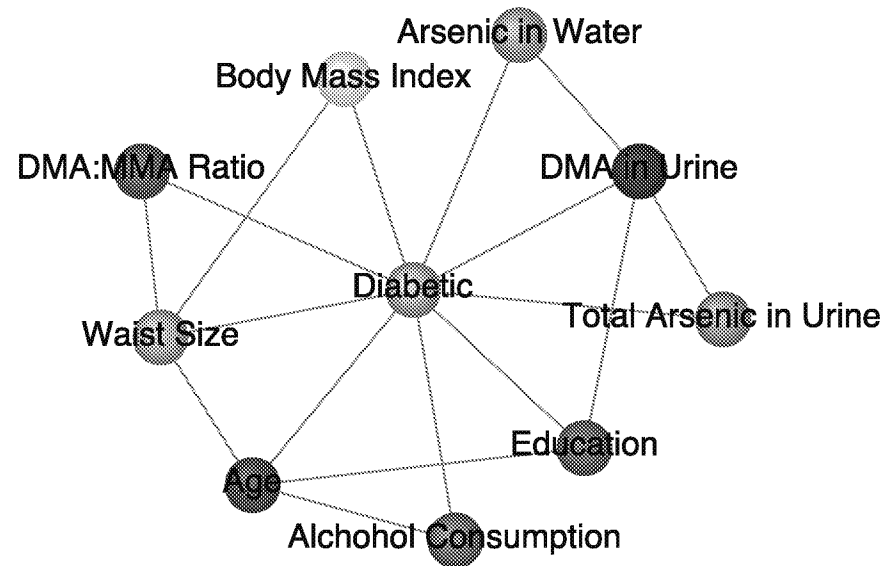
- **Stage 2:**

- $EOG = \gamma_0 + \vec{X}_1 \vec{\gamma}_1 + \rho \widehat{BLL} + v$

EOG = end-of-grade test result

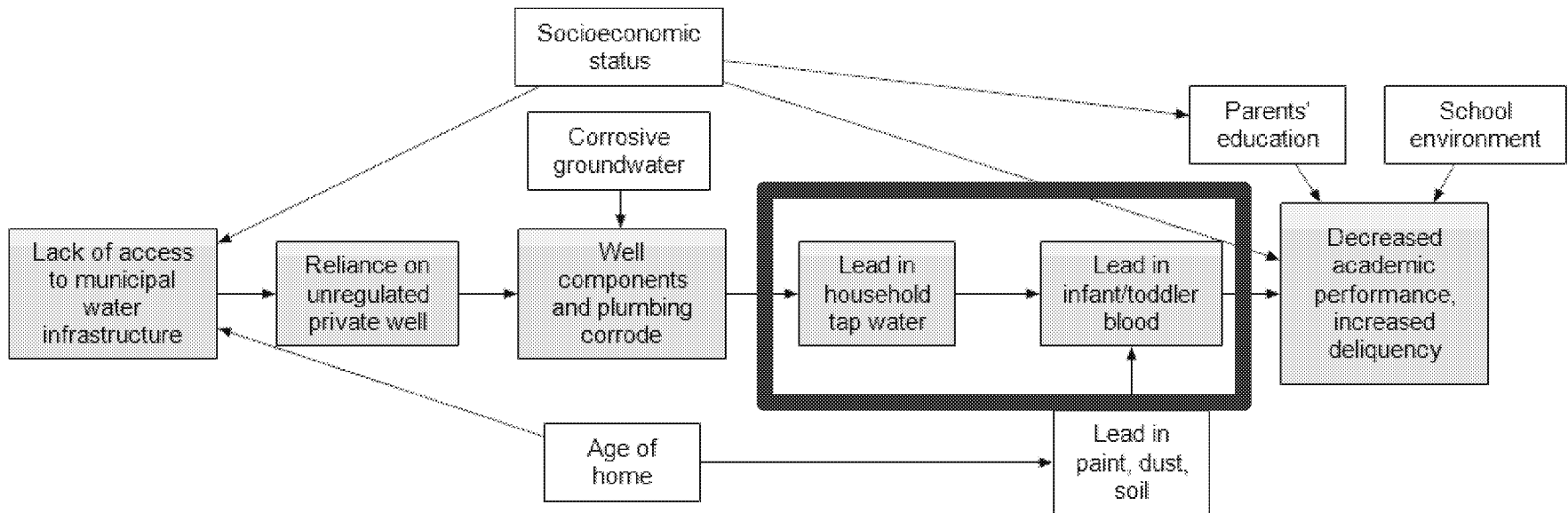
Explore Interacting Natural, Built, Social, Environment Factors via Bayes Networks

- **Graphical representation of variables in a system**
 - Linked by probabilities
- **Used in medical diagnostics, marketing, many other areas**
- **Recently modelled diabetes risks from arsenic in drinking water**



Bayesian network model of diabetes risks from arsenic in drinking water.

Task 2: Effects of Lead in Private Well Water on Lead in Children's Blood



Hypothesis: Child blood lead levels increase significantly with increases in lead in the household tap water.

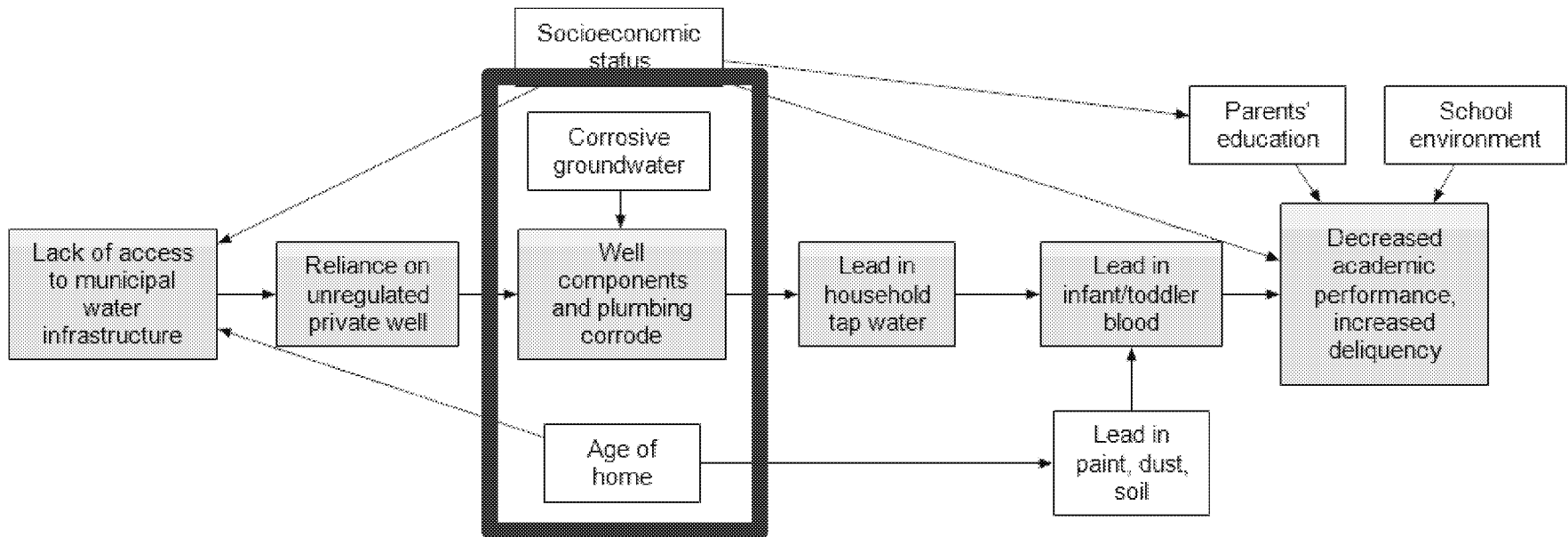
Field Study to Identify Water, Blood Lead Relationships

- **Recruit 300 houses**
- **Collect first-draw tap water, dust, child blood samples**
- **Chemical analysis at RTI**
- **Regress blood lead on estimated cumulative lead in water/ body weight**



Gibson research group members with participating household.

Task 3: Identify Lead Sources

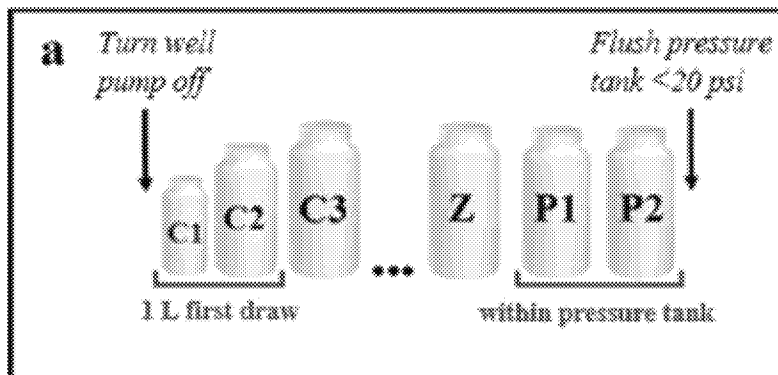


Hypothesis 1: Tap flushing decreases lead in most homes.

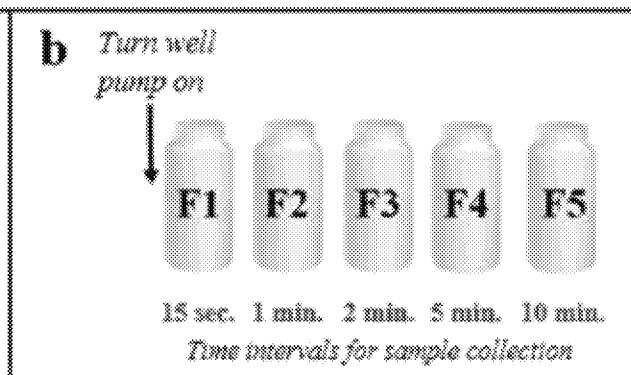
Hypothesis 2: In a subset of homes, flushing increases lead via mobilization of particulate lead.

“Well Profiling” Method Pioneered by Marc Edwards, Virginia Tech

Sequential sampling of home plumbing
Section 3.2.1



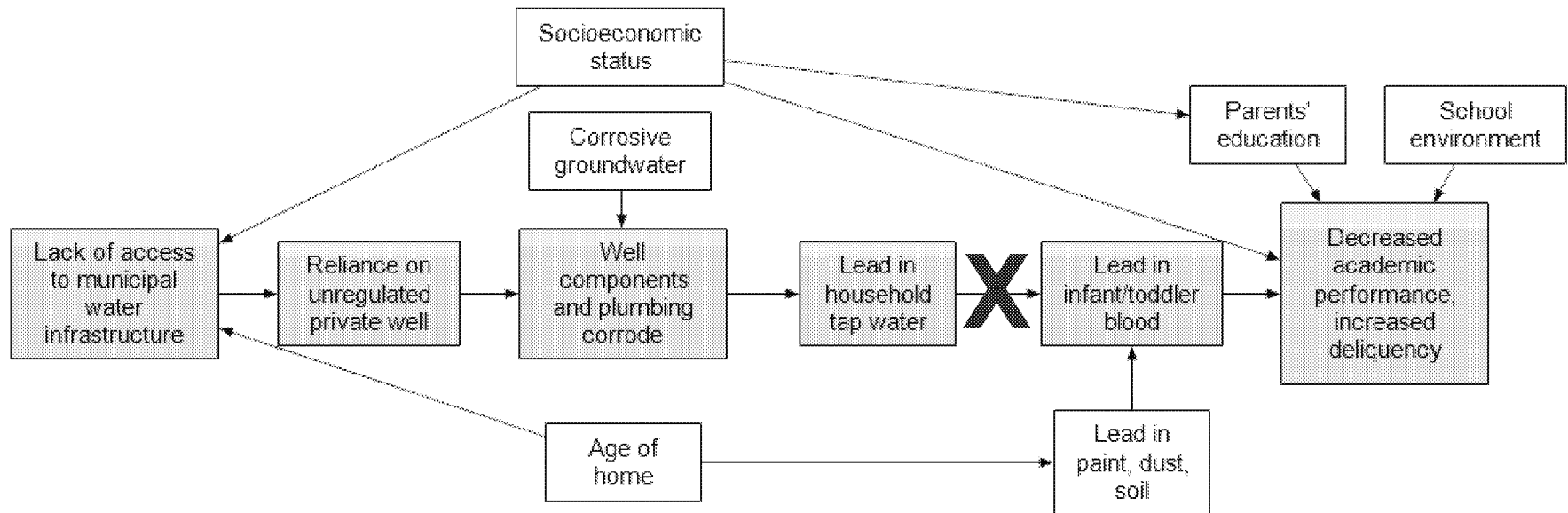
Flushing series for well sampling
Section 3.2.2



- 20 households
- First set of samples characterizes lead from plumbing
- Second set identifies if well components are a source

SOURCE: Pieper KJ, Krometis LA, Gallagher D, Benham B, Edwards M. 2015. Profiling Private Water Systems to Identify Patterns of Waterborne Lead Exposure. *Environ Sci Technol* 49:12697–12704; doi:10.1021/acs.est.5b03174.

Task 4: Improve Water Stewardship to Break the Causal Chain



Hypothesis: Risk communication will prompt water testing and action to prevent lead exposure.

Risk Communication Design Uses Mental Models Approach

Identify what people need to know to make more informed decisions.

- Expert influence diagram

Identify what people already know and how they make their decisions.

- Focus groups, surveys

Design communication content.

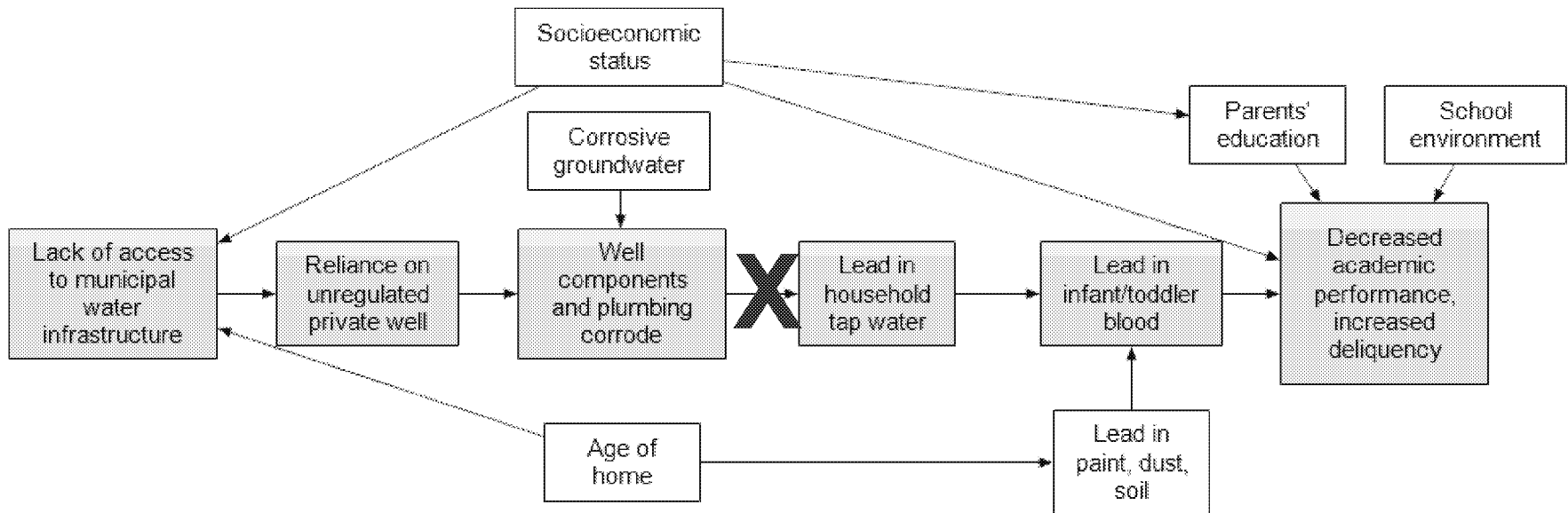
- Correct misperceptions, reinforce accurate beliefs

Test effectiveness of communication content.

- Randomized-controlled trial

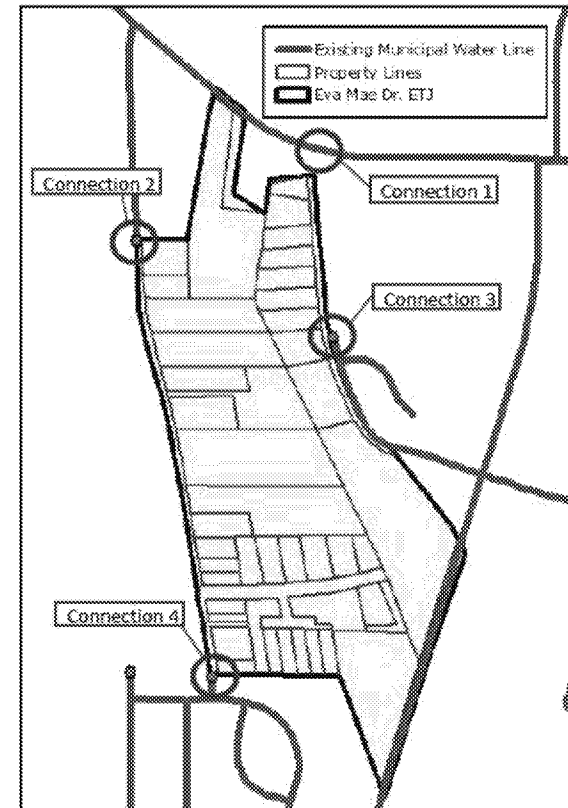


Task 5: Assess Technical Solutions to Breaking Causal Chain



Cost-Benefit Analysis of Four Options

- **Tap water flushing (using results from lead profiling experiments)**
- **Bottled water use for drinking and cooking**
- **Household water treatment (whole-house or under-sink)**
- **Municipal infrastructure extension**



Potential connections to Raleigh public water supply for one underbounded neighborhood.

Research Team

Jackie MacDonald Gibson

**Associate Professor, Environmental Engineering
University of North Carolina Chapel Hill**

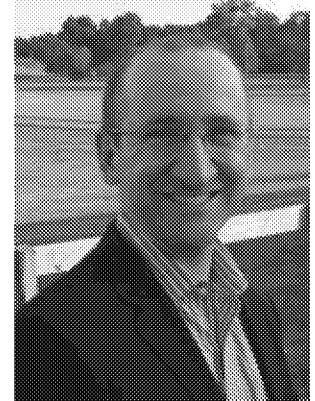
- **Researching underbounded communities since 2012**
- **Previous Associate Director, Water Science & Technology Board, National Research Council**
- **Education:**
 - **PhD, Department of Engineering and Public Policy, Carnegie Mellon**
 - **PhD, Department of Civil and Environmental Engineering, Carnegie Mellon**



John M. MacDonald

Professor of Criminology and Sociology, University of Pennsylvania

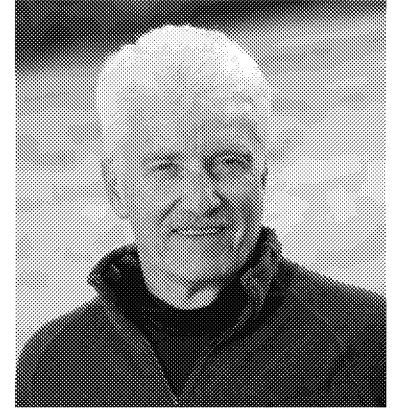
- **20 years of experience researching juvenile and social justice policies**
- **Built environment effects on crime**
- **Kershaw Prize from the Association for Public Policy Analysis and Management for policy contributions by age 40**
- **Education:**
 - **PhD, Criminology, University of Maryland**



Philip J. Cook

Sanford Professor Emeritus of Public Policy, Duke University

- **Microeconomic methods for impact evaluation**
- **Crime and truancy prevention a major research focus**
- **Elected to National Academy of Medicine**
- **Education:**
 - **PhD, Economics, University of Michigan**



Keith Levine

**Senior Research Chemist and Director,
Analytical Sciences, RTI International**

- **Leads analytical chemistry team in measuring trace elements in environmental and biological samples**
- **Extensive publication record in analytical chemistry**
- **Education:**
 - **PhD, Atomic Spectrometry, Wake Forest University**



Michael Fisher

**Assistant Professor, Environmental Engineering
University of North Carolina at Chapel Hill**

- **Expertise in water treatment, study design, water quality sampling and analysis**
- **Extensive prior experience in water research in urban, peri-urban, and rural areas of sub-Saharan Africa**
- **Education:**
 - **PhD, Environmental Engineering, University of California, Berkeley**



Wändi Bruine de Bruin

**Leadership Chair in Behavioural Decision Making,
Leeds University Business School (UK)**

- **Focuses on understanding and informing how people make decisions**
- **Extensive prior experience with environmental risk communication**
- **Served on multiple expert panels on scientific risk communication**
- **Education:**
 - **PhD, Behavioral Decision Theory and Psychology, Carnegie Mellon**



Frank Stillo

**Doctoral Candidate, Environmental Sciences
University of North Carolina at Chapel Hill**

- **MSPH and early doctoral research documented high prevalence of lead and bacteria in water in underbounded communities**
- **Has led outreach to underserved communities**
- **Education:**
 - **MSPH, University of North Carolina at Chapel Hill**



Other Key Team Members

Students

Abishek Komandur

Sydney Lockhart

Allison Clonch

Erica Wood

Peter Kane

Nurse-Phlebotomist

LaQuinta Kincaid



Progress to Date

Table with tasks and progress

Task	Progress
1. Underbounding effects on blood lead, children's outcomes	Data use agreements completed with relevant agencies; data expected soon
2. Water lead effects on children's blood lead	Household recruitment under way; 15 recruited, 10 sampled
3. Lead sources in tap water	Not yet begun
4. Risk communication to encourage water testing	Mental models surveys completed; communication designed; randomized controlled trial under way
5. Technical options analysis	Preliminary municipal water extension designs for four neighborhoods completed

Summary

- **Some peri-urban African American neighborhoods lack connections to nearby municipal infrastructure.**
 - Structural racism
- **Risks of drinking water contamination are high.**
 - Lead prevalence comparable to Flint
- **Effects on children's blood lead and related outcomes are unknown.**
 - Affected by built, natural, and social environments
- **Research will help identify comparative benefits, costs, and feasibility of interventions.**

Underbounding Occurs Nationwide

Latino neighborhoods in Modesto, Calif., excluded from sewer service, storm drains, street lights



MacDonald Gibson Group

Relevant Publications

- DeFelice, Nicholas B., Jill E. Johnston, and Jacqueline MacDonald Gibson. "Reducing Emergency Department Visits for Acute Gastrointestinal Illnesses in North Carolina (USA) by Extending Community Water Service." *Environmental Health Perspectives* 24.10 (2016): 1583–1591.
- Fizer, C. M., W. Bruine de Bruin, F. J. Stillo, and J. MacDonald Gibson. In press. Barriers to managing private wells and septic systems in underserved communities: mental models of homeowner decision making. *Journal of Environmental Health*. 16 manuscript pages.
- Leker, H., and J. MacDonald Gibson. 2018. Relationship between race and community water and sewer service in North Carolina, USA. *PLoS ONE* 13(3):e0193225 (pp. 1-19). DOI: 10.1371/journal.pone.0193225.
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- Naman, Julia Marie, and Jacqueline MacDonald Gibson. "Disparities in Water and Sewer Services in North Carolina: An Analysis of the Decision-Making Process." *American Journal of Public Health* 105.10 (2015): e1–e7.
- Stillo, F., and Jacqueline MacDonald Gibson. "Exposure to Contaminated Drinking Water and Health Disparities in North Carolina." *American Journal of Public Health* 107.1 (2017): 180-185.
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Selected Additional References

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- Joyner, Ann Moss, and Carolyn J Christman. *Segregation in the Modern South : A Case Study of Southern Moore County*. Cedar Grove Institute for Sustainable Communities. 2005.
- Lichter, Daniel T. et al. "Municipal Underbounding: Annexation and Racial Exclusion in Small Southern Towns." *Rural Sociology* 72.1 (2007): 47–68.
- Marsh, Ben, Allan M. Parnell, and Ann Moss Joyner. "Institutionalization of Racial Inequality in Local Political Geographies." *Urban Geography* 31.5 (2013): 691–709.
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